



## VACUUM AND BEAM LIFETIME IN THE DOUBLER

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A. Asumptions and Parameters

## 1. gas composition

warm region ( $300^{\circ}\text{K}$ ) :  $\text{H}_2$  and COcold region ( $4.6^{\circ}\text{K}$ ) :  $\text{H}_2$  and He

## 2. fractional length

warm region : 7%

cold region : 93%

## 3. beam emittance at 1 TeV (horizontal and vertical)

$$E(90\% \text{ of the beam}) \equiv 6\pi\sigma^2/\beta = 0.02\pi \times 10^{-6} \text{ m-rad.}$$

## 4. total nuclear scattering cross sections

(information supplied by Roy Rubenstein)

H	He	C	N	O
42 mb	135 mb	335 mb	390 mb	440 mb

5. relative sensitivity of ionization gauge (normalized to  $\text{N}_2$ )

$\text{H}_2$	He	CO	$\text{N}_2$
0.450	0.226	1.06	1.000

(P. A. Redhead, J. P. Hobson and E. V. Kornelsen,  
The Physical Basis of Ultra High Vacuum)

6. The average pressure in the cold region  $P_C$  is related to the (warm) gauge reading  $P_G$  by the relation

$$P_C = \sqrt{T_{\text{cold}}/T_{\text{gauge}}} \cdot P_G = \sqrt{4.6/300} \cdot P_G = .124 P_G$$

7. Particles are lost by a nuclear scattering regardless of the scattering angle.
8. Multiple Coulomb scattering increases the beam emittance but the beam loss by a single Coulomb scattering is negligible.

B. Results

Fig. 1 Current loss rate by nuclear scattering

fractional gas composition

warm	$H_2 : F$	$CO : 1 - F$
cold	$H_2 : F$	$He : 1 - F$

$$\frac{I \cdot dI}{I dt} = - (100 \times R_W \times P_W + 10^4 \times R_C \times P_C) / \text{sec}$$

$R_W$  and  $R_C$  are plotted as a function of  $F$ .

Example

warm	60% $H_2$ , 40% CO	$R_W (F=0.6) = 0.35$	$P_W = 1 \times 10^{-8} \text{ Torr}$
cold	75% $H_2$ , 25% He	$R_C (F=0.75) = 1.44$	$P_C = 5 \times 10^{-11} \text{ Torr}$

$$\begin{aligned} \frac{I \cdot dI}{I dt} &= - (10^2 \times 0.35 \times 10^{-8} + 10^4 \times 1.44 \times 5 \times 10^{-11}) / \text{sec} \\ &= -(0.35 \times 10^{-6} + 0.72 \times 10^{-6}) / \text{sec} = - 1.07 \times 10^{-6} / \text{sec} \end{aligned}$$

loss of current = 4% after 10 hours

Fig. 2 Emittance increase by multiple Coulomb scattering

$$E \equiv 6\pi \sigma^2 / \beta = 0.02\pi \times 10^{-6} \text{ m-rad (horizontal and vertical)}$$

$$\frac{1}{E} \frac{dE}{dt} = (100 \times R_W \times P_W + 10^4 \times R_C \times P_C) / \text{sec}$$

Example

warm 60% H<sub>2</sub>, 40% CO      R<sub>W</sub> (F=0.6) = 0.85      P<sub>W</sub> = 1 × 10<sup>-8</sup> Torr

cold 75% H<sub>2</sub>, 25% He      R<sub>C</sub> (F=0.75) = 0.91      P<sub>C</sub> = 5 × 10<sup>-11</sup> Torr

$$\begin{aligned} \frac{1}{E} \frac{dE}{dt} &= (100 \times 0.85 \times 10^{-8} + 10^4 \times 0.91 \times 5 \times 10^{-11}) / \text{sec} \\ &= (0.85 \times 10^{-6} + 0.46 \times 10^{-6}) / \text{sec} = 1.3 \times 10^{-6} / \text{sec} \end{aligned}$$

increase of emittance = 5% after 10 hours

C. Comments

1. The average pressure in the warm region P<sub>W</sub> will be higher by a certain factor compared to the gauge reading. The factor must be obtained either by calculation or by measurement.
2. For a head-on collision, the luminosity L is proportional to I<sup>2</sup>/E:
$$\frac{1}{L} \frac{dL}{dt} = 2 \frac{1}{I} \frac{dI}{dt} - \frac{1}{E} \frac{dE}{dt}$$
3. It is believed that, for the colliding mode, the doubler aperture is no more than 0.5π mm-mrad in both horizontal and vertical directions.
5. Vacuum requirement near the interaction point must be evaluated separately from the background consideration.

Fig. 1.

Current Loss by Nuclear scattering

$$\frac{1}{I} \frac{dI}{dt} = -(100 R_W P_W + 10,000 R_C P_C) / \text{sec}$$

P<sub>W</sub> : average pressure, warm region

P<sub>C</sub> : average pressure, cold region

R<sub>C</sub>

R<sub>W</sub>

F

1.0  
0.9  
0.8  
0.7  
0.6  
0.5  
0.4  
0.3  
0.2  
0.1  
0.0

warm region: H<sub>2</sub> = F, CO = 1-F  
cold region: H<sub>2</sub> = F, He = 1-F

gas composition

(no H<sub>2</sub>)

2

1

3

3.

Fig. 2

Emittance Increase by Multiple Coulomb Scattering

$$\frac{1}{E} \frac{dE}{dt} = (100 R_w P_w + 10000 R_c P_c) / \text{sec}$$

$E = 0.02\pi$  mm-mr at 1 TeV

$P_w$  : average pressure, warm region

$P_c$  : average pressure, cold region

gas composition

warm region:  $H_2 = F$

$CO = 1 - F$

cold region:  $H_2 = F$

$He = 1 - F$

$R_c$

$R_w$

2.

(no  $H_2$ )

1.

